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THE TRAINING OF A GEOLOGIST

By JOHN C. BRANNER, Ph. D.
State Geologist of Arkansas.
Professor of Geology in the Leland Stanford Junior University.

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The Training of a Geologist.

[Presidential address before the Indiana Academy of Sciences, Indianapolis, December 30th, 1889.]

By John C. Branner, Ph. D.

The fitting of a young man for his work in life is worthy of our serious study and consideration, and while much that I may say is equally applicable to men in any calling, I can only undertake to speak of some of the demands that the times are placing upon geologists.

It is to be expected, of course, that there are plenty of persons of intelligence in the world who have no conception whatever of a geologist's duties, those who imagine that geology as a profession can be picked up just as the duties of certain civil offices, or of clerical positions, may be readily learned and performed by any man of ordinary intelligence. Among the applications I have received for employment upon surveys under my direction, one man gave as a reason why he should be employed that he was a consistent member of the Presbyterian church; another that he was a graduate of a famous military school; another was interested in geology and had read many books upon the subject, among which he cited some of the vaporings of Ignatius Donnelly; still another used to be acquainted with professor Winchell, and another was in poor health and thought field work would be good for him. At least half of the applicants have asked for employment because they understood ordinary land surveying, and one of them admitted that he had no other qualification than that he was "a good hand to camp out."

The general academic training of a geologist during the first two or three years of his college course is not essen-

tially different from that of any man of culture. I am not disposed to side with those who think that if a man is to be a specialist the sooner he begins his specialty the better. In a general way this proposition is correct, but in making such an admission it must be distinctly understood that all things which tend to broaden a man's scholarship form essential parts of his specialty.

That a man should have a knowledge of history, philosophy, social science, and of literature in general goes without saying. But as bearing directly upon his professional career he should understand, of the languages, at least Latin, French, and German. And by "understanding" I don't mean that he is to be satisfied with being able to laboriously dig out translations from these languages, but that he must be able to read them at sight, and with some degree of fluency. In mathematics he should have the general instruction required by civil and mining engineers, and should give some attention to astronomy and geodesy. In chemistry the more thorough his training the better, and besides the usual work required of students of chemistry, in which especial attention should be given to inorganic chemistry, he should be a skilled mineralogist and should be well acquainted with metallurgical processes. In physics the student should give attention to optics, especially as employed in the construction of mathematical instruments; to hydraulics and hydrostatics, to dynamics and to hypsometry.

I have sometimes thought that to be a good and successful geologist one should first be a good civil engineer and then a good mechanical and mining engineer. This thought has been suggested to me by my own experience as an engineer and by the fact that among the students I have had to train in geological work those from the engineering courses have, almost without exception, proven themselves by far the best qualified. This is due to the fact that a large part of a field geologist's work consists in tracing out in the field, and the delineation upon maps and cross sec-

tions, of structural features. In this work topographic features—the elements of horizontal and vertical distances—have to be so constantly dealt with that unless the student has pretty thorough training as an engineer he will find the work tedious, and will constantly tend to slight the very parts in which he is least trained. I should make it plain, however, in referring to the desirability of a geologist having an engineer's training, that I do not mean to imply that an engineer can always step into geology and make a success of it, for it is only the young engineer who either can or will subordinate his technical training as an engineer to the ends to be reached in a geological investigation. As a rule the man who has been a practicing engineer for a number of years is no longer sufficiently pliable in habits of work and thought to make a successful geologist. In geology various degrees of detail are required. Sometimes our measurements need to be made with a micrometer, at others with a foot rule, while at other times an error of several feet or of several hundred feet is of no consequence, but a civil engineer who has been accustomed to the degree of accuracy required in railway construction cannot always bring himself to use now a less accurate method, and now another of great precision, just as circumstances may require. But whether the student receive the full training of a civil and mining engineer or not, he will need to acquaint himself with the use and adjustment of instruments and with practical and theoretical land surveying. He should have a thorough practical knowledge of the various methods of doing topographic work and of map making. He should be a good draftsman; he should be so trained in drawing that he can, if necessary, make his own drawings and sketches and will know how to direct the work of others. Careful attention should be given to the methods of petrographic investigation, to the preparation of rock slides and their microscopic study. In paleontology he should not only be instructed in the best methods of investigation in and the application of paleontology to geologic work,

but he should also have a pretty thorough acquaintance with fossil forms and their range in the geologic column; and in this connection I would insist upon the necessity of botanic and other biologic studies in so far as they aid paleobotany and paleontology.

I take it for granted that no one in this audience has any doubt in his mind about the necessity of laboratory work in training a naturalist, and I would not refer to this point at all were it not that within a couple or three months the faculty of an educational institution in this country after an exhaustive debate of three and one-half hours, decided by a vote of 6 to 5 that laboratory work in the scientific courses should not be abolished as requested by the professors of languages. Of course one would as well try to teach a student to swim without letting him go nigh the water as to undertake to teach him natural history, chemistry or physics without laboratory work.

Besides laboratory work there is perhaps no branch of natural history which more emphatically demands field work for its students than does geology. This is due largely to the fact that the little indoor or laboratory work the geological student can do is directly and entirely dependent upon his field work. Then, too, in other studies we can have and do have our labaratories in which nearly all the student's observations are made. In botany and in zoölogy, in histologic studies and in chemistry and physics, the materials may be successfully studied in the laboratory, but the geologist, whose studies are often valuable in proportion to the range of his direct observations, can not take his stratigraphy and his topography into a laboratory. His laboratory, except in certain parts of petrographic and biologic studies and in the office work on his maps, is out of doors.

In its professional bearing the most essential part of a geologist's training should be to the end *that he observe well, and that in his deductions he properly subordinate his facts.* His preliminary technical training should therefore be for

the purpose of teaching him accuracy and detail; and the necessity of accuracy should be so deeply impressed upon his mind that accuracy will become a part of his nature. After this lesson is learned he must be taught speed, and that, too, without sacrificing in the least his accuracy.

As the whole professional training of the geologist is for the purpose of enabling him to reach correct conclusions, he should be trained in the use of every method of investigation that will aid him, and among these methods I count as of great importance that of multiple working hypotheses. Dr. Chamberlin, President of the University of Wisconsin, recently delivered an address before the Western Society of Naturalists, upon this subject, in which he presented in detail the advantages of this method of scientific investigation. In my own experience I have found it of the greatest value and I know of no better way of developing the reasoning powers or of anticipating difficulties, or of reaching right conclusions than by the proper use of hypotheses. I have laid some stress upon this point because I find that there are those who think that a man of science can have nothing to do with hypotheses, that he must confine himself to facts. And it will not be out of place for me to caution young naturalists against what I may call the "debating society" style of reasoning. The old-fashioned debating society is calculated to increase one's intellectual agility, but as its object is the training of advocates, its influence on a man of science is harmful to the last degree, for, as I have said elsewhere, a scientific man must be a judge—not an advocate.

Besides having a broad general culture, a geologist must be *par excellence* a geologist, and besides being a geologist he ought to know more about some particular branch of geology than anyone else. The material progress of our times is due largely to that division of labor which enables each individual to perfect his skill. Progress in science is due in no small degree to a similar division in scientific work. Though I cannot dispense with a knowledge of

chemistry, specialization by my neighbor who devotes himself to chemistry relieves me of the necessity of devoting a large part of my time to chemistry; the devotion of another to physics gives me my time for geologic work proper, which, without the specialist in physics, I should be obliged to devote to physical studies. The astronomer hands me the results of his special investigations and saves me my time for geology, which, without his help I should be obliged to give to astronomy. And so it is all around. On the other hand I trust that my attention to geology will in its turn, come to the aid of the chemist, the physicist and the astronomer.

In saying a word for specialties I am fully aware of all that has been urged against this kind of scholarship. The president of one of our greatest educational institutions said to me in a private conversation a few years ago, that he had his doubts and fears about the outcome of this modern tendency among scientific men to specialization. Said he: "If this thing goes on, we shall have after awhile a man who will know all about the stripes on a trilobite's tail, but he won't know anything else." It is very easy to ridicule a specialist, especially if the aims of his studies are not comprehended. Galvani studying the twitching of a frog's legs, Darwin breeding pigeons, and Agassiz planting sticks on a glacier, are inspiring or ridiculous in proportion as we comprehend the bearing or end of their studies. Whether studying the twitching of a frog's legs or the stripes on a trilobite's tail is an unworthy and contemptible occupation for an intelligent man depends, therefore, upon the ultimate objects of the study. And in regard to special work by those who aspire to broad culture in science, I can only repeat what I have already said upon this subject, that a man who is incapable of doing and has not done special investigation is not capable of taking a broad view of science in any of its relations. Mr. Darwin has done some of the best generalizing of our age, but before he did it he had done some of the best of specializing, and that too on

such unpractical, uninteresting and useless animals as the barnacles.

But while we must confine ourselves to a certain extent to specialties, care should be taken to not unnecessarily diminish the field of our observations. There is a tendency on the part of a certain class of specialists, particularly well developed among some of the German investigators, to put everthing under the microscope. This is an excellent way of seeing some things; but it is as difficult to examine a landscape with a microscope as it is to examine bacteria without one. Many questions in geology can be studied satisfactorily only when we take a broad view of our subjects, and some discretion must be used in the application of methods.

A lofty structure cannot be built upon a narrow foundation, neither can a man be great in science who hasn't broad culture. And as only close attention to minor details in the material used can secure a great building against calamity, so care and skill in special investigations—in little things as it were—are essential to a great and broad-minded man of science.

You will probably exclaim that the requirements of which I speak and which I find essential are entirely too many to be complied with; that life is too short to allow one to undertake so much purely preliminary work. It cannot be denied that to become a good geologist is a serious undertaking, and all I have to say in reply to this objection is that this is the kind of geologist the world wants. How many have we ? you will ask Not many, I must confess. Indeed men with such preparations are few, and when one finds them, he doesn't find them "looking for a job"; their services are always in demand. I may say, however, that it is not to be expected that the student should get all this training as undergraduate work. College men going into law, medicine and theology, if they get the technical training required by their professions, spend two or three years in law, medical or theological schools. The geologist must

do what amounts to the same thing—that is, he must, beyond his general training, qualify himself specially for geologic work. When our geologists are so trained we shall have a better science, better geologists and better results all round.

The demands that are made upon a geologist require no particular kind of an intellect, save, of course, that it be a good one, but broad culture and broad mental grasp are essential to the pronounced success of any man in any calling. It is also of great importance that one should be capable of prolonged and concentrated thought; indeed, unless one is capable of such concentration he can never hope to rise above mediocrity. Fortunately in this respect we all have control, or can by some exertion have control, of our mental dispositions. The problems of geology require a great deal of physical exertion, the accumulation of a vast number of facts, but these facts are of little importance as compared with the philosophical use to which they should be put. And it is in this intellectual arena that the man of science is really put to the test. Men are wanted nowadays not to make a collection of this or that, not to work up this or that deposit as it may occur in some limited area, or this or that formation, and much less some county or other artificial area, but who, in working up a topic, can and will take up the problem as a whole, and study it as a whole, not in one locality, but wherever it may be found in the world, who can work up the bibliography of his subject, and who can sift and put to good use the facts gathered by others in his deductions, and whose knowledge of allied sciences will enable him to draw proper conclusions from his facts, while his knowledge of affairs will render his judgment upon economic questions of the greatest value.

But it is not my purpose to confine my remarks entirely to the technical training of the geologist, but to refer also to certain general and ethical features of his work which call for training or fitness to which educators give too little atten-

tion. I hardly know whether any instructor ever troubles himself to impress his students with the ordinary requirements of professional etiquette; I don't remember ever having heard the subject mentioned in a class-room. We seem to have depended upon men's instincts as gentlemen for shaping their professional conduct.

To be a successful geologist one must be a geologist very largely because he can't help it—because he can't keep out of it. I mean, of course, that the science must so fill the demands of his mind, his temperament, and his tastes, that in any other occupation he feels that he is not where he can make the most of himself and of his energies. Such men will have that professional pride, zeal, and ambition, without which everyone is doomed to a fatal mediocrity. The man who goes into geology because there is money in it, will, in nine cases out of ten, make a failure of it—he will get neither the money nor the geology. To be sure, a living must be had, but he who has the right training, and the right interest in his work, will never lack for lucrative employment for any considerable length of time. It may sometimes happen, however, that a geologist is without such employment for a while, but it should be distinctly understood that such times are not to be given over to demoralizing idleness. The world is too full of problems of scientific interest for any man having a scientific spirit to stand idle for a single day or a single hour, and no one having such a spirit will stand idle.

In the balancing of the essentials and the non-essentials in the training of a geologist certain economic considerations have, almost without exception, to be faced. Those of us who devote ourselves to pure science are constantly being wearied with that most tiresome of all questions about the practical value of what a man reads about, thinks about, or does. So long as the young see around them examples of men who have become wealthy by the successful application of some law in science, by the invention or discovery of something that people are willing to pay handsomely

for, just so long shall we have these young men asking how this and that study, this and that bit of training are going to be of any *use* to them. As men who love science for its own sake, we get weary of such questions, and some of us feel driven, in order to emphasize our warnings, to avoid the useful altogether. Thus we occasionally have, on the one hand, men who have a horror of doing anything that is liable to be of practical value, and on the other, men who have no patience with an investigation which does not promise some tangible, material reward for their pains. My opinion is that there is little to choose between in these two types. One of them is just as far wrong as the other. But whether one devotes himself to the economic questions of geology or to its purely scientific questions should be decided by one's own tastes and fitness as far as possible; but it must not be forgotten that pure science can dispense with the economic features of geology, but that economic geology cannot safely dispense with pure science. In any case, then, attention must be given to geology as a pure science.

There are many pitfalls in the pathway of the geologist—many inducements for him to profit just a little too much by his experience. His duties are often of a very delicate nature; he is called upon to examine and report upon properties where large sums of money are involved, and where the information obtained in his professional work might be used by him for his personal advantage. The importance of a right way of thinking and acting in this connection is of the utmost importance, for if one does not conduct himself properly just here he is liable to gain a good share of the whole world "but to lose his own soul." I am reminded to quote the man who advised his son to "never mind the evil itself, but avoid the appearance of evil." This is, of course, a perversion of good advice. "Avoid the very appearance of evil and evil will avoid you," is good advice for the geologist, as well as for other folks.

I may say briefly that a professional geologist, especially if he is in a public place, such as state geologist, or is in any way connected with a state or national survey, has no moral right to have a personal interest in any mining property, or in any other property a knowledge of the value of which might come to him through his knowledge of geology. Abstaining from such interests is a duty the geologist in public employ owes to himself as well as to the public, and the public has the right both to expect and to demand that its employés shall not walk off with the profits of its investments, just as a manufacturer has the right to demand that his employés shall not appropriate the articles they make. The geologist not in public employ who becomes personally interested in mining operations, even when he does it in the frankest, most open, and most upright manner, and with no idea of doing otherwise than as any citizen may honorably do, does nothing wrong in itself, but he must remember that he is risking his reputation and standing as a consulting geologist.

The man who is not willing—does not try—to save his energies, may be relied upon to not give the world the benefit of his best services. How often we see men who have an idea that there is some virtue in doing a thing the hard way, who, when suggestions are made for the purpose of saving their energies, assure us that they'll get it done, and if their way is a little harder, they are the losers by it. Unfortunately they are not the only losers.

A certain engineer has a three-sided scale in his drafting room. There are six different scales cut upon it. A person using this scale is liable in taking it up to turn the wrong division upon his line, and, in order to avoid this risk, and to save the time and thought that must be used in watching to see that one doesn't get the wrong side, a simple piece of metal has been devised to clasp it in such a way that it is impossible to use the wrong side. Some of his assistants remove this safety attachment, because they are not "used to it" and insist on running the risk of making

mistakes and of using up the time they are paid to work, in examining their scale to see whether they have turned it over. Another man doing topographic work doesn't want to signal to his assistant, preferring to call out his directions to him at long distances, often more than a quarter of a mile, so that at the end of the day he has done three-quarters of a day's work on the topography, and the other quarter in yelling—a bit of labor the geologist can not utilize. These mistakes are examples of unpardonable errors of judgment, against which young men should be warned. If we spend our time and energy in unnecessary work we shall have just so much the less energy for the essential. There may be some excuse for the man who isn't able to discriminate between the essential and the non-essential, but in such cases as those referred to, and indeed in the majority of cases that arise, there can be no such question. In his methods the geologists must always be willing to profit by the experience of others. Methods and appliances of research are constantly being improved, but these improvements are made, not by disregarding the experience of others, but by making every possible use of it.

There is sometimes a tendency among the newly fledged to imagine that those who have gone before them have not taken the greatest pains in their work, that their conclusions have not been warranted. They therefore begin with the idea that by the application of superior, or at any rate, new methods of investigation, they are going to upset everything done before they began. Such persons often succeed in making asses of themselves, and end their careers before they begin them—that is they make careers impossible.

I had occasion recently to go over the work of one of our older geologists—work done under the most adverse circumstances. This work had but a short time before been very sharply criticised by an aspiring young geologist, and I was prepared to find either one of them right. I not only found the work of the older geologist well done, but

I was astonished at the clearness of his perceptions and the general reliability of his conclusions. The young man had committed a blunder from which his reputation can never recover.

The necessity of caution on the part of the young geologist in publishing conclusions that one feels to be open to criticism, or when he sees that important facts may have been overlooked, can not be too strongly emphasized. The publication of facts is generally useful, but deductions can afford to wait until they are properly matured. A most valuable piece of advice once given me was to the effect, that young people would better not begin pumping out of their intellectual reservoirs before something has been pumped into them. Life is too short, and progress all along the line is too slow for us to cumber the march of science with verbose discussions which help toward strife and contention instead of toward truth and union. "The longer anyone studies a vast subject, the more cautious in inference does he become."* To be sure "ignorance is no reason with a fool for holding his tongue," but my advice is not intended for fools, who will be fools in spite of everybody and everything, but for those who, having sound sense, desire not to appear fools or to bring discredit upon themselves or upon the science to which they are devoted.

Science is not infrequently charged with vacillation. Apropos of this some one remarks: "Science says—but no matter what science says, for the next time she says anything she'll say just the opposite." We cannot deny the justness of the implied criticism, but that it is just must be attributed entirely to premature utterances. We have some sad examples in this country of poor geologists whose premature conclusions, drawn from too hasty or incomplete work, have kept half a dozen good geologists busy for years in correcting their mistakes and in putting the truth before the world. Their excursions into geologic fields are like the inroads of lawless and unclean animals

* Bryce's American Commonwealth, Vol. I, p. 4.

that require a score of persons to clean up and put things straight after them. These busy-bodies have, almost without exception, an itching for notoriety that leads them to seek some scientific short-cut by which to arrive at distinction, but if there is a balancing of accounts either here or hereafter, these men are destined to have a distinction in the scientific world of quite another sort from that for which they are pining. They are usually men of good enough intentions, but as one of my preceptors once reminded me: "we have a right to expect something more than good intentions of men." All people mean well; it is our business to *do* well.

Sensationalism has done and is doing great injury not only to geology but to other branches of science. There are certain features about every science that impress the uninformed with their novelty, and there are certain persons who are always ready to make capital out of them. This gives rise to a sort of "O my!" class of men and to an "O my!" kind of science. Such people delight in the startling; none of the more radical theories of science, theories put forth by the right thinking with great caution, stagger them. Man's descending from a monkey never troubled them; they always thought so, and can point out cases of descent that would make Mr. Darwin or Mr. Wallace catch his breath. This skimming the surface, this dilletanteism is strong in our times. In the geologist's training the less we have of the sensational the better it will be for the science and for the man.

It is not a pleasant thing to be obliged to destroy the delusions which people hold close to their hearts, but the conscientious geologist has a good deal of this disenchanting to do. And nobody ever thanks him for it; while the very persons he may hope to serve in telling them the truth, will, in all probability never believe him and never forgive him. But a geologist has to face a great many disagreeable duties, and if he hasn't the moral courage to tell the plain, unvarnished truth, and to take the consequences,

when a white lie would smooth matters over all round, he will find his troubles increasing as time goes on. One lie, whether it is a white one or a black one, only makes room for two others, and the man who makes two lies grow where but one grew before deserves no mercy.

Those who are at once workers in science and teachers of science know how difficult it sometimes is to draw a sharp line between what we know and what we simply believe, but so far as possible this distinction should always be kept before the minds of students, and no effort should be spared to prevent that dazing of their minds which prevents them from weighing evidence and from distinguishing between simple truth, legitimate hypotheses, and simple figments of the imagination.

And now just a word about our responsibilities to our own intellects. Intellect is the tool with which the geologist has to do his work. If that tool is bent out of shape or dulled by improper use it cannot perform its functions properly. It is highly essential therefore that he keep his intellect unimpaired. He should strive to keep his mind free from those tricks of logic, rhetoric and sentiment by which so many of us allow ourselves to be imposed upon. Those of us who are naturalists and investigators at heart, as well as by profession, are not satisfied with declaring that we are "open to conviction," while parenthetically we add, "but we'd just like to see the man who can convince us." We are bound by every sentiment of honesty to go where our evidence leads us, whether it takes us to a pleasant place or not. Truth must be our companion whether she be an agreeable or a disagreeable one—a handsome or an ugly one. We cannot honestly say to reason, "thus far shalt thou go, but no farther;" we can't reasonably follow the science of geology to a certain point and then abandon it for the divining rod or spiritualistic seances or clap-trap appliances of any kind. The man who has no notion of accepting the results of his reasoning would just as well not reason at all, while the man who undertakes to

reason within certain limits insults his intelligence. All honest men are seeking the truth; and is it not our duty to help others in this search when we can? We may be sure that if we wait till all the world thinks alike, the world will never care what we think.

I have said that the profession of a geologist requires certain proficiencies that are common to successful men in any and all occupations in life. Good judgment, clear insight, business habits of thought, and promptness of decision and action are as essential in geology as anywhere else, and it has often seemed to me to be even vastly more so. It is not enough that one should plod faithfully ahead with a task—though faithful plodding is not to be underestimated at all. The man who grasps a subject in all its bearings, takes hold of it with judgment and solves its problems with courage and logic is the one who really advances the cause of truth, the cause of science and the cause of humanity.

Once upon a time a business house employed a young man whose energy and grasp of the business of the firm induced the head of the house to promote him more rapidly than an old and faithful employé. The old employé felt deeply hurt that this dapper young fellow should be advanced over him, and he took occasion to complain of it to the senior partner. The senior partner felt it to be a case that he couldn't very well argue with so faithful and tried a servant. There happened to be a lot of wagons passing the door of the building at the moment, and, as if changing the topic for a minute, he asked the old clerk what was making all that noise. He went forward and returning told the partner that it was a lot of wagons going by. He then asked the clerk what the wagons were loaded with. He went out again and returned and reported that they carried wheat. He sent him again to know how many there were of them. He returned with the reply that there were 16. Again he sent him to ascertain whence they came, and he returned saying they were from the city of

Blank. The senior partner then asked the clerk to be seated, and sending for the young man complained of, said: "Will you see what the meaning is of that rumbling noise in front?" The young man replied: "It will not be necessary, for I have already ascertained. It is caused by some wagons—36 in all—16 in this lot, but 20 more to pass to-morrow. They belong to Pinta & Rosa of the city of Blank and are loaded with wheat. They are on the way from Blank to Zee where the supply of wheat is short, and is now fetching $1.15 a bushel, while it costs but 90 cents at Blank. The wagons get 15 cents a bushel for hauling it, and each one carries 100 bushels." The young man was then dismissed and the senior partner turning to the old clerk said: "My friend, you see now why Mr. So-and-so has been promoted over you."

This illustrates the demands, not of business men alone, but of geologists, and of everyone who employs others, either directly or indirectly, or who associates others with himself in his work. We all want men who can not only do the very best and most thorough scientific work, but who comprehend their duties in all their relations, meet emergencies with prompt and clear judgment, and save us and our energies for other affairs. And we don't want to be obliged, in order to get out of a man what there is in him, to stand over him constantly and to direct his every effort.

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